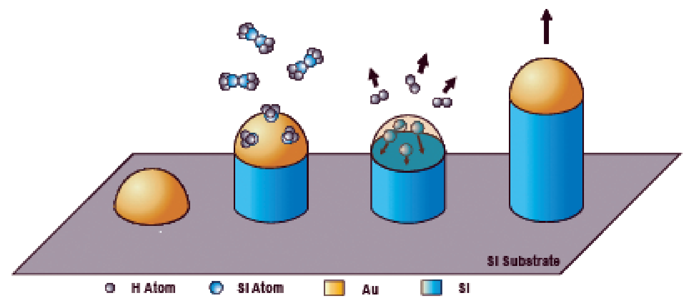
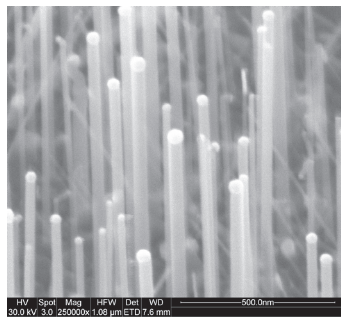
LALP-07-085 Fall 2007

Nanowire technologies for radiation detection applications

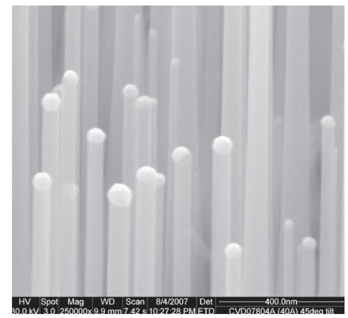
Nanometer-scale science and technology is a rapidly growing component of Los Alamos National Laboratory's (LANL) research and development portfolio. Unique properties that emerge when materials are fabricated with nanoscale dimensions have led to novel electronic and photonic applications that stand to significantly impact fields important to the Laboratory's core missions.

Recently, Los Alamos researchers have begun to explore ways in which materials in nanowire form can be developed for radiation detection applications. Properties such as widely tunable electronic bandgaps and high-density pixelization of nanowire arrays promise to provide new platforms and approaches for radiation detection.





Ge nanowires



SiGe alloy nanowires

Focus

Three teams at LANL have been developing independent approaches to nanowire synthesis. These include nanometer-scale lithography and film growth via neutral atom beam techniques; chemical vapor deposition on metal nanodot "seeds;" and thermal deposition into patterned alumina templates.

Each of these approaches has its own advantages and as a group they represent a unique resource for creating nanowires from a very broad range of materials. Elemental solids such as bismuth, silicon, or germanium, and a variety of compound semiconductors can all be fabricated in nanowire form with these techniques.

This large set of accessible materials represents a unique advantage. It gives us the flexibility to address detection of different radiation types and energies—from low energy neutrons to high energy gamma rays. This will allow us to contribute to a broad cross section of radiation detection applications that are vitally significant to both homeland security and threat reduction.

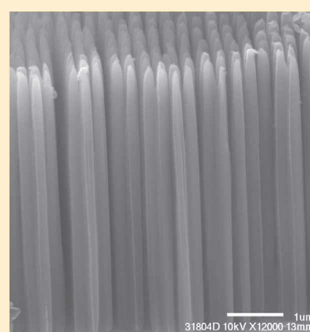
Key contacts

Nanowire fabrication capabilities exist in the Materials Physics and Applications, Materials Science and Technology, and Chemistry Divisions.

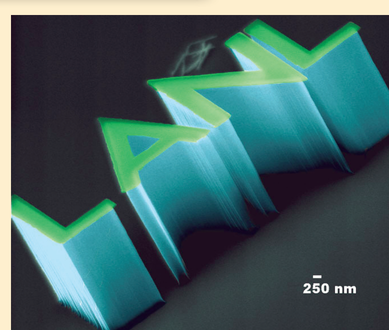
- Nanoscale lithography and thin film growth via neutral atom beam methods:
  Mark Hoffbauer (C-ADI), *mhoffbauer@lanl.gov*
- Chemical vapor deposition synthesis of semiconducting nanowires:
  Tom Picraux (MPA-CINT), *picraux@lanl.gov*
- Alumina template assisted nanowire deposition:
  Geoff Brown (MST-8), *geoffb@lanl.gov*

Current sponsors: Laboratory-Directed Research and Development program, National Nuclear Security Administration, Department of Energy Office of Basic Energy Sciences program

Principal customers: National Nuclear Security Administration, Department of Homeland Security, Defense Advanced Research Projects Administration, Defense Threat Reduction Agency

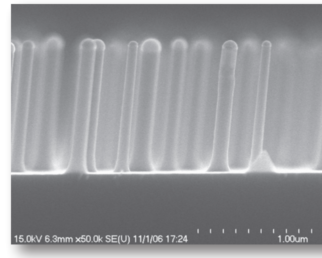


Nanoscale structures formed with neutral atom beam lithography.



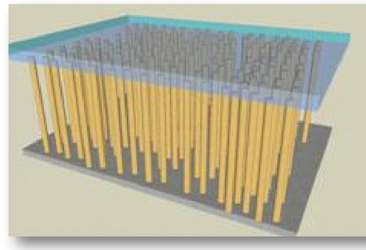
Materials solutions @ Los Alamos

Semiconductor nanowire synthesis



The Center for Integrated Nanotechnologies (MPA-CINT) houses a state-of-the-art low pressure chemical vapor deposition system for the synthesis of semiconducting nanowires using the vapor-liquid-solid technique. This computer-controlled cold wall system enables control of nanowire length and diameter, in situ electrical doping for device fabrication, and heterostructure formation. Current research is focused on Si, Ge, and SiGe alloys because of their wide relevance to electronic and sensing applications.

Typically, nanowires are fabricated with diameters between 10 and 100 nm. Considerable effort is being focused on the directed assembly and integration of the nanowires into microscale systems. Integration is considered a key step for application of nanowires to electronic and sensing areas. Of particular interest for sensing applications is current work on the development of a cross-bar array architecture to allow contacting of nanowires at high density in an individually addressable format.



Template assisted nanowire deposition

In the Structure/Property Relations Group (MST-8) we have implemented nanowire fabrication by vacuum vapor deposition into patterned alumina templates. In this method a porous alumina template is heated in vacuum and held above a molten charge of the material to be grown as nanowires.

Vapor from the material penetrates the pores of the template and condenses as the template is cooled. The template pores define the nanowire length and diameter. Thin templates with straight, regularly spaced pores from 200-nm down to 5-nm diameter and various packing densities are commercially available, providing a wide range of possibilities for nanowire fabrication. With careful attention to thermal gradients and stresses many different materials can be used with this technique.

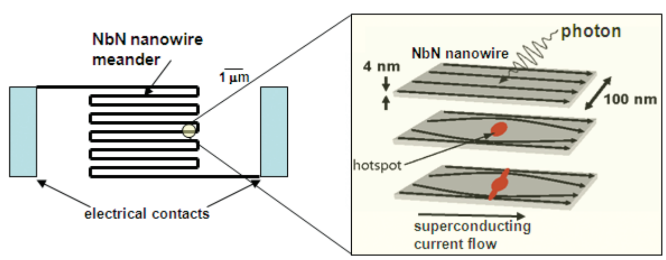
After deposition, the alumina can be left in place as a support structure for the wires and electrodes or it can be etched away to leave loose, or freestanding nanowires.

The figure above shows nanowire arrays forming in three regions of an alumina template that is masked by a metal back plate.

Energetic neutral atom beam lithography and epitaxy (ENABLE)

A unique nanofabrication facility in LANL's Chemistry Division is used for etching high-aspect-ratio nanostructures and for growing high quality nitride and oxide-based semiconducting thin film materials. When combined with available electron-beam and optical lithography, nanowire structures can be produced from semiconducting, superconducting, and photonic materials. ENABLE's low temperature conditions facilitate the formation and integration of nanoscale materials in ways that are not possible with conventional technologies. For example, complex nanoscale structures fabricated into polymer materials can be used as templates for making superconducting nanowire-based arrays for detecting and imaging single photons.

The ENABLE technology makes possible the development of novel semiconductor materials and nanostructures for efficient photon, neutron, x-ray, and gamma-ray detection with imaging capabilities across a broad energy range.



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